ACELL for Physics?

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Abstract: *This paper considers the use of the chemistry laboratory work evaluation process ACELL (Advancing Chemistry by Enhancing Learning in the Laboratory) as a tool for evaluating and improving physics laboratory work. In November 2007 an ACELL-style workshop for physics was run at the University of Technology Sydney as part of the* Forging new directions in physics education in Australian universities *project, funded by the Australian Learning and Teaching Council (ALTC). One stream of this project is looking at undergraduate laboratory work in physics, and the ACELL process is a means of evaluating laboratory work developed by the chemistry eduction research community, hence it may be of great value in physics also. The purpose of this workshop was to consider the ACELL evaluation process as a model for evaluating undergraduate laboratory exercises in physics. The workshop was attended by more than 50 delegates, from 19 universities, and eight physics experiments were presented for evaluation using ACELL templates. The delegates were surveyed during and after the event on how appropriate they found the ACELL evaluation process for physics experiments, and what modifications would be needed to implement such a process for physics. The results of these surveys are presented with recommendations for modifying the ACELL process for application to physics experiments.*

Introduction

Laboratory work supports the teaching and learning of undergraduate science in higher education (Khoon and Othman 2004) and the physics perspectives on the goals of undergraduate laboratories are discussed in American Association of Physics Teachers (AAPT 1997). Recently, we have noticed trends that erode the time spent on traditional laboratory work such as the introduction of computer-based activities in the laboratories and the reduction of time spent in laboratories to allow time for other learning activities. In this scenario, each laboratory experiment is precious and needs to be carefully examined. If we have fewer experiments, they need to be great and not just good. Pedagogy researchers also appear to be doing less research on experimental laboratories.

In the Australian context, a current ALTC-funded physics discipline based project has a dedicated Working Party on undergraduate laboratory work with the aims of developing processes and materials to assist physics educators in improving their laboratory courses. This project follows on from earlier work which identified examples of good practice in laboratory learning highlighted in the ‘Snapshots: Good learning and teaching in physics’ booklet (Learning Outcomes and Curriculum Development in Physics Project 2005). At a workshop held in association with the 2007 UniServe Science conference at The University of Sydney a list of desirable learning and other outcomes for laboratory courses was identified. This list included realistic problem solving skills, active engagement of students, experimental design, data collection and analysis skills, record keeping, error analysis, team work, communication, planning and time management. Ways of achieving these outcomes incorporated a mixture of recipe-driven and open-ended labs, group work and mini-projects were discussed. In addition, a presentation was made by representatives of the Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL) project, describing the approach taken by some in the chemistry education community to laboratory development and evaluation (see ACELL 2008a for details). The undergraduate laboratory Working Party has since been considering whether the ACELL approach to laboratory design and evaluation is applicable to undergraduate physics teaching.

To this end, a workshop applying the ACELL process to a collection of physics experiments was held at the University of Technology, Sydney (UTS), in November 2007. The workshop was run in collaboration with the Australian Council of Deans of Science, who are currently undertaking a project focussing on laboratory learning across all science disciplines.

What is ACELL?

ACELL has two overarching goals. The primary goal is ‘to make available tested, educationally sound laboratory experiments, which may be used to improve the quality of learning in laboratory courses’ (ACELL 2008a). The secondary goal is to develop a community of practice amongst chemistry educators.

For each experiment, the preliminary ACELL evaluation procedure (Buntine, Read, Barrie, Bucat, Crisp, George, Jamie and Kable 2007) requires an ‘ACELL template’ which deals with several educational and practical issues. The authors or proponents of particular experiments collect or produce the experiment script, demonstrator notes, technical notes, notes on OHS issues or risk assessment and education notes. The education notes require a summary of the experiment including its place within the course, which year it fits into, students’ requisite prior knowledge, the purpose of the experiment and its desired outcomes and requires the proposer to clarify learning objectives and the processes by which these are to be learnt and indicators by which the learning may be assessed. The experiments are then presented at a workshop where ‘students’ (some actual undergraduates, some demonstrators and some academics) undertake the experiment and then provide feedback on them using surveys and facilitated feedback sessions after the experiment.

Only those experiments which meet a pre-determined set of criteria (ACELL 2008b) are placed on the ACELL database as ‘experiments under review’. In the next stage, authors or proponents respond to recommendations from the preliminary evaluation. Following this, extensive data is gathered from students in an authentic learning environment. If these results meet the criteria then the experiment becomes an ‘ACELL experiment’ on their website and the authors can pursue publishing their work in one of the journals with which ACELL has a publication agreement (twelve such published experiments are listed on the ACELL web site, see for example Wajrak and Rummey,’ 2004). If the experiment does not meet the criteria then the authors can carry out several iterations of feedback and improvements. If an experiment does not meet the criteria, and the authors do not carry out further iterations, a draft experiment is taken off the website.

The process is long and requires considerable investment of time. However, it does ensure that individual experiments are educationally sound and aligned with their learning objectives. The intent is not to check the chemistry or the overall laboratory program, but rather to provide individual experiments which others can modify and adapt into their local environments. Academics will have expertise in their own discipline, but it is likely that educational expertise could be enhanced. The ACELL process has been set up to provide precisely that.

The ‘ACELL for physics’ workshop at UTS

The workshop at UTS in November 2007 was run in the manner of an ACELL workshop but on a smaller scale. It was a single day workshop in which eight experiments were presented in two sessions (morning and afternoon). By contrast, the 2006 ACELL workshop was of three days duration and 33 experiments were presented.

Eight experiments were put forward by academics from six different universities on a range of topics including thermal physics, AC and DC electronics and waves and oscillations. The academics completed the ACELL education templates for their experiments, containing the information required under the ACELL process. A booklet containing this information was printed and given to all attendees on the day. The experiments were then undertaken by groups of 'students'. The 'students' were a mixture of academics, including lecturers and some deans of science from 19 different universities, and undergraduate students.

The day started with a welcome from the ALTC project team leaders, and a short introduction by ACELL representatives to the ACELL project and process. At the completion of the experiments the 'students' evaluated both the experiments and the educational templates provided with the experiments. This evaluation was done by completing feedback surveys. In the morning session academics worked with academics and students with students; in the afternoon session students were paired with academics. Further feedback on the experiments was provided in discussion sessions at the end of the day. There was a discussion group for each experiment which included the academic who put forward the experiment, the 'students' who did the experiment and a member of the ACELL group to help facilitate the discussion. Much useful feedback was provided by the 'students', and it also provided an opportunity for the academic who acted as demonstrator to better explain the educational context of the experiment. The day was completed with a large group de-brief on their experience of the workshop process, led by ACELL representatives.

Following the workshop, a survey was sent to all participants asking for their views on the day. This included questions on how they found the experience as students, how useful the event and the feedback had been to those presenting experiments and whether they would support such an approach to evaluating physics experiments or participate again in such a workshop.

Feedback from the 'ACELL for physics' workshop at UTS

The feedback from the discussion sessions at the UTS workshop and from the subsequent survey was generally very positive. Participants enjoyed the day and found it a valuable experience. The most positive aspect reported by the majority of survey respondents (12 out of 18) was the opportunity to network with other people interested in learning in laboratories. This was also mentioned in discussions on the day. Networking and professional development through the workshops is one the aims of ACELL.

Academics also mentioned that they appreciated the chance to consider pedagogical outcomes of their experiments, this opportunity largely coming from completing the educational template in advance of the workshop, and then reinforced in discussions with the 'students' (real or *faux*) in the feedback sessions following the experiments. Another positive aspect was the stimulus to consider the issues faced by students in labs. This second point was raised spontaneously several times by academics doing experiments on the day of the workshop.

The discussion sessions and surveys completed on the day provided good opportunities for participants to give their views on the experiments presented, and there was almost unanimous agreement that there was adequate opportunity to provide feedback on the day.

Concerns raised in discussions and later echoed on the surveys included the lack of understanding of the context in which experiments are undertaken, particularly in terms of how they fit into course context and the prior knowledge, experience and skills of students doing the experiments in their usual setting. It was also noted that some experiments presented were cut-down versions rather than the complete version done at their home institutions, while other experiments presented had substantial pre-laboratory work and preceding experiments designed to prepare students for the experiment. This preparatory work could not be presented at the workshop. The ACELL workshop process and templates as used did not allow participants to do this preparation, even had they wanted to, as they did not know in advance which experiments they would be doing or have the laboratory notes.

Two participants presenting experiments commented that the evaluation process is not realistic due to the time commitment required by participants to genuinely understand the experiments in their real contexts, as this is not possible in the few hours allocated to an experiment in an ACELL workshop.

Most participants indicated that the ACELL approach, either in its current form or with some modifications, would be suitable to apply to physics experiments. However there was concern that the amount of time required by the people preparing and presenting experiments at an extended workshop was unrealistic, and could not be done on a regular basis, unless the process was supported by funding, and by recognition of its value in departmental workload models. The prospect of a publication associated with the evaluation process was a definite positive for some participants, and would provide incentive to participate as proponents of experiments.

In summary, the response to the workshop was in general very positive, with most participants indicating that they found it useful. The majority interest in participating in future workshops suggests that the experience has met a significant need for physics departments to systematically evaluate laboratory work. The concerns such as described above relate to the efficiency and viability of the process. The actual ACELL process was considered useful and applicable to physics experiments, with perhaps some small modifications. These modifications include providing more information in advance on how to prepare templates and providing workshop participants with notes on the experiments in advance, which include any pre-laboratory work, and more information on the role of the individual experiments within the course contexts.

Progress and questions

A tangible outcome of the trial 'ACELL for physics' workshop is that three experiments have passed the first review criteria and are going forward to evaluation by students at their own institutions. Two academics have already adopted experiments which they saw at the trial workshop in their own departments, with some modifications to suit the courses at those institutions.

In June 2008, a further ALTC physics workshop on the higher-year laboratory work, was held at Monash University. Key goals were to ascertain the qualities and abilities which were desirable outcomes from laboratory courses for a physics graduate and the means by which these may be achieved. A particular focus was the potential of projects and open-ended experiments for developing student initiative and investigative skills, deep understanding, teamwork and planning skills. It was recognised that demonstrator experience and skills were critical to this enterprise.

The workshop concluded with consensus by participants on two important ways forward. First, that the physics departments represented would value the opportunity to share resources. Second, the wider dimension of the overall laboratory programme within the physics major was critical, so that any collective effort should focus on identifying common needs and meeting them. The importance of laboratory learning within the degree program is demonstrated by current work such as Feteris (2007) and Richardson, Sharma and Khachan (in press).

Limitations of the approach and implications for physics

When we compare the capability of the ACELL process with the list of desirable learning objectives and ways of achieving them (such as those from the physics discipline workshop associated with the

2007 UniServe Science conference, listed above), we immediately see a mismatch. First, the ACELL process only considers single experiments whereas an entire undergraduate lab course may bring together group work, open-ended or mini project work, and other course-wide practices (such as having no laboratory time limit, and different ways of linking laboratory work to lectures). Second, there is no simple way in which the ACELL process can be applied to project work, particularly where the project work is highly dependent on student input. Some of the examples of best practice showcased in the ‘Snapshots’ booklet (Learning Outcomes and Curriculum Development in Physics Project, 2005) could not have been evaluated or published using the ACELL system, although these are evidently of great value as laboratory learning exercises. It may be possible that in physics there is greater opportunity for students to play with the design of experiments, from simple first year experiments with scripts that give students the aims but no explicit method for an experiment, to substantial third year projects. In contrast, chemistry has a greater focus on specific techniques and instruments.

The question then arises, do the objectives of the ACELL process differ substantially from what the physics education community want to achieve? Are there any ideas that may be transferred or adapted from ACELL to evaluate the valued components of physics laboratory which do not fit the traditional experiment mould? What kind of approach would assist in evaluating student-directed projects or entire laboratory programs? This is a critical consideration since projects of various kinds are increasingly being used in physics laboratory education see for example Neumann and Welzel (2007), and other papers in the May 2007 special issue of the *European Journal of Physics* which focus on student laboratory work.

Conclusions

Experiencing the ACELL process has promoted thinking about how we may achieve better outcomes from physics laboratory courses. Some of the key goals of laboratory courses have been identified, and the ACELL process is one way of evaluating experiments which achieve these outcomes. However there are limitations in the ACELL approach. In particular the range of activities to which it can be applied is limited and does not include some important aspects of laboratory programs such as project work. More work is needed to then assess the sort of tools which would be able to evaluate these. There are also issues with the amount of time required to complete the ACELL process.

The ACELL workshop approach does have a role in sharing resources, in encouraging participants to think critically, in pedagogical terms, of the experiments they experience or present at the workshop as well as their own laboratory experiments. The workshop aspect is also an excellent opportunity for networking and professional development.

Hence, while further tools are needed beyond the ACELL process for evaluating physics laboratory work, the ACELL process may have a valuable role to play in physics laboratory learning.

Acknowledgements

Support for this work has been provided by the Australian Learning and Teaching Council, an initiative of the Australian Government Department of Education, Employment and Workplace Relations. We would also like to thank Justin Read and the other ACELL directors for their contributions to the workshop and many useful discussions. We would also like to acknowledge support from Dean of Sciences project, and staff and students involved in the UTS Workshop, particularly those from UNSW, Macquarie, La Trobe and University of Adelaide who presented experiments. This work has Human Ethics approval HREC 07-2007/98921.

References

AAPT, (1997) American Association of Physics Teachers, goals of the introductory physics laboratory, *The Physics Teacher*, **35**, 546–548.

ACELL (2008a) http://acell.chem.usyd.edu.au/homepage.cfm.

ACELL (2008b) ACELL Guidelines and procedures. http://acell.chem.usyd.edu.au/publicdocs/guidelines_and_procedures.pdf.

Buntine, M.A., Read, J.R., Barrie, S.C., Bucat, R B., Crisp, G.T., George, A.V., Jamie, I.M. and Kable, S.H. (2007) Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL): a model for providing professional and personal development and facilitating improved student laboratory learning outcomes. *Chemistry Education Research and Practice,* **8,** 232–254.

Feteris, S. (2007) *Student Learning in Undergraduate Laboratories***,** PhD Thesis, Department of Physics, Monash University.

Khoon, K.A. and Othman, M. (2004) Some thoughts on the introductory course in physics. *College Student Journal,* **38**, 503.

Learning Outcomes and Curriculum Development in Physics Project (2005) *Snapshots: A resource booklet from the project Learning Outcomes and Curriculum Developments in Physics: Good Learning and Teaching in Physics in Australian Universities* Monash University, Melbourne.

Neumann, K and Welzel, M. (2007) A new labwork course for physics students: Devices, Methods and Research Projects *European Journal of Physics,* **28**(3), S61–S70.

Richardson, A., Sharma, M.D. and Khachan, J. (2008) What are students learning in practicals? A cross sectional study in university physics laboratories. *CAL-laborate International,2*0–27.

Wajrak, M. and Rummey, J. (2004) Determination of silver by differential pulse anodic stripping voltammetry: An APCELL experiment. *Australian Journal of Education in Chemistry,* **63,** 26–30.

Wilson, K., Mills, D., Sharma, M., Kirkup, L., Mendez, A. and Scott, D. (2008) ACELL for Physics? In A. Hugman and K. Placing (Eds) *Symposium Proceedings: Visualisation and Concept Development,* UniServe Science, The University of Sydney, 133–136.